ENGINEERING CASE LIBRARY

ECL 232

CROP SPRAYING BOOM FOR CESSNA 185 (A)

This case documents the analysis made by H. Aass Aero Engineering to ensure that the installation of Crop Spraying Boom in lieu of Atomizer Spray System on Cessna 185 aircraft complied with MOT requirements.

Written by P. A. Moylan, Chief Designer,
H. Aass Engineering under the direction of
Professor G. Kardos for Carleton University.

CROP SPRAYING BOOM FOR CESSNA 185 (A)

On May 20, 1975, Lorne Pollock entered the office of H. Aass Aero Engineering, an aeronautical consulting firm, with a job to be done. Morne was employed with Chemical Control Research Institute, (CCRI), a branch of the Canadian Department of Environment. He was the chief pilot and director of the experimental agriculture division; his job included spraying fields of test crops from the air with new and "on the market" insecticides to study their short and long term effects.

H. Aass Aero Engineering was founded in 1969 by Haakon Aass because he recognized that many private aircraft operators were having difficulty getting modifications approved quickly by the Ministry of Transport (M.O.T.) because of simple red tape delays. Haaken assumed that a small private company could process this paperwork more quickly and this idea was feasible since he had been granted a D.A.R. licence (Design Approval Representative) by MOT. This meant that he could act for MOT and approve or dissapprove modifications. Many of the operators began to consult the new company before they initiated any of their own changes. The operation now consisted of Haakon, myself as Chief Designer, two draftsmen and a secretary. In this position I was usually called into these initial meetings with the customer. I had joined the company in 1971 as a junior draftsman and had worked my way up to the point where I was now Haakon's right-hand man. After one year with the company I enrolled in Carleton University in Mechanical Engineering as a part-time student.

At the first meeting between Lorne Pollock, Haakon and myself, Lorne presented an idea he had been "kicking around" for a while.

Apparently, his department at CCRI had recently purchased a Sorenson atomizer spray rig for it's Cessna 185 aircraft. Lorne was extremely dissatisifed with its performance and was determined to upgrade the system. The rig had been installed as a kit consisting of a fibreglass chemical holding tank slung beneath the belly of the aircraft, a propellor driven pump at the forward end of the tank and two atomizers supported under each wing by a tubular tripod arrangement (Exhibit I).

Lorne explained that while "crop-dusting" with this new equipment, he noticed that the insecticide was not being distributed evenly. Rather, it was forming into narrow columns behind the atomizers which left long strips of untreated greenery in the test field below. He had brought this problem to the attention of his co-workers at CCRI with his solution. He had designed a spray boom, a long straight pipe with a series of fifteen spigots mounted on the trailing edge. Lorne believed that this set-up would prove to be far more efficient than the Sorenson rig. However, Lorne was unfamiliar with engineering procedures and specifications and was now presenting us with the problem of attaching his new fourteen foot booms to the airplane, one under each wing.

The problem was complicated because only a maximum down-time of one day was available for the aircraft, because the time for spraying certain fields was very critical. Lorne's aircraft was on the field at the moment, he informed us, but he had work to do in North Bay the following afternoon and he had to leave in about three hours. He planned to return in two weeks for one and one-half days and then go on

an assignment which required the new spray system. Down-time problems are not infrequent in dealing with private operators, consequently many modifications have to be prepared in kit form for ease of installation....in the field if necessary. My job was to come up with a means of fastening the new booms that would require only one day for installation, without having the aeroplane around for reference.

One hour later, I was out on the field with Lorne examining his aircraft. He presented me with a set of Sorenson drawings showing installation details of the atomizer. He also gave me a six-inch section of the new boom as a sample to work from. As he boarded his Cessna, he explained that the new design would work best if the pipes were inclined outboard 5^{o} to the ground.

Returning to the office, I opened up the set of drawings Lorne had given me.

"Any ideas?" I queried as Haakon looked over my shoulder.

"It seems to me" he replied, "that the simplest solution would be to use the same wing pick-up points."

"True" I added, "but we'll need a whole new set of struts."

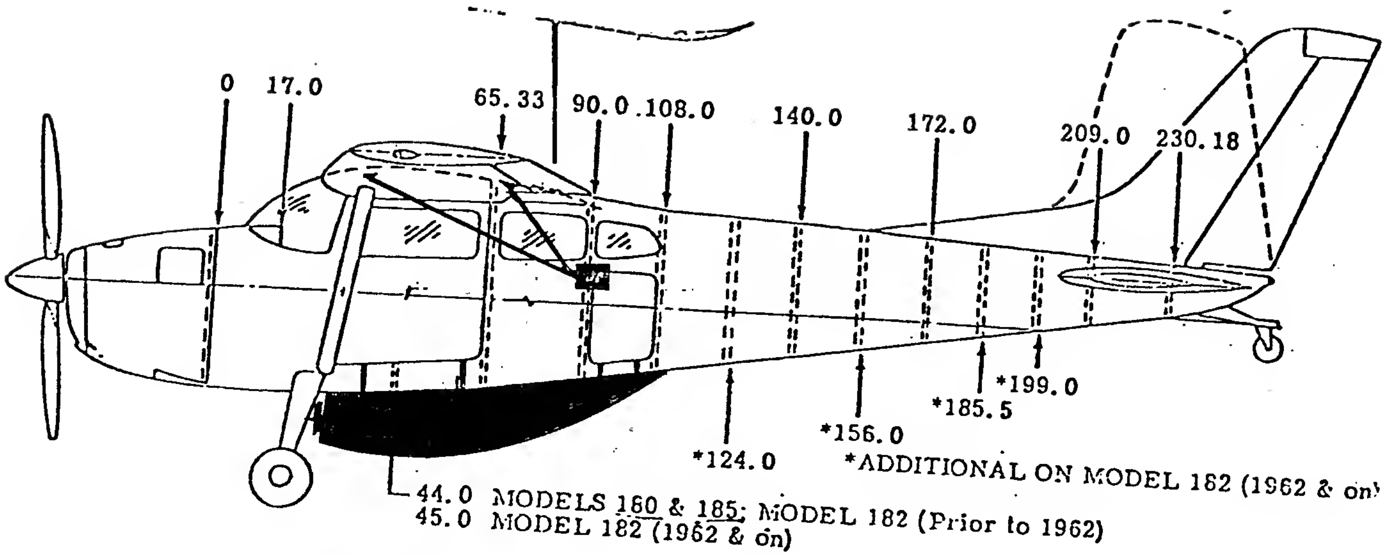
The pick-up points that Haakon referred to were the original reinforced areas under the wing and as I examined the drawing, I noticed that there were two sets of these for each wing, and each set included three individual brackets. One of the brackets of the set was situated close to the leading edge of the wing while the other two were just forward of the flaps and ailerons. The first set was located about half way out along the wing and the second set, about half the remaining distance again. These points had been "beefed up" with doublers (i.e., an

extra thickness of skin) on the inside and two small angle brackets on the outside to accommodate the Sorenson tripods. I had an idea about attaching the new struts and booms but I would have to do some calculations first. I sincerely hoped that the new configuration transmitted the same or less load to the wing brackets than the original mod. If so, I was home free, but if not, an additional beef-up would be necessary, a very man-hour consuming job at installation time.

In order to carry out my initial investigation a specific strut had to be chosen. Often, such a choice depends on what is available and this case was no exception. Normally, round steel tubing would be the most desirable since side loads are not created when moving through the air. The only material of this type with a sufficiently small diameter, 1/2" to 5/8", had a very heavy wall which meant additional weight for the already marginal weight safety factor. Fortunately, I found some streamlined steel tubing 5/8" wide and 1 3/8" along the major axis. It was light and most important, there was enough of it to do the job. Returning to the office, I worked from sketches of present and new rigs, and set about proving my hypothesis. (Exhibit II).

EXHIBIT I

CESSNA 185 WITH SORENSON SPRAY RIG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17.0
65.33
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*124.0
*156.0
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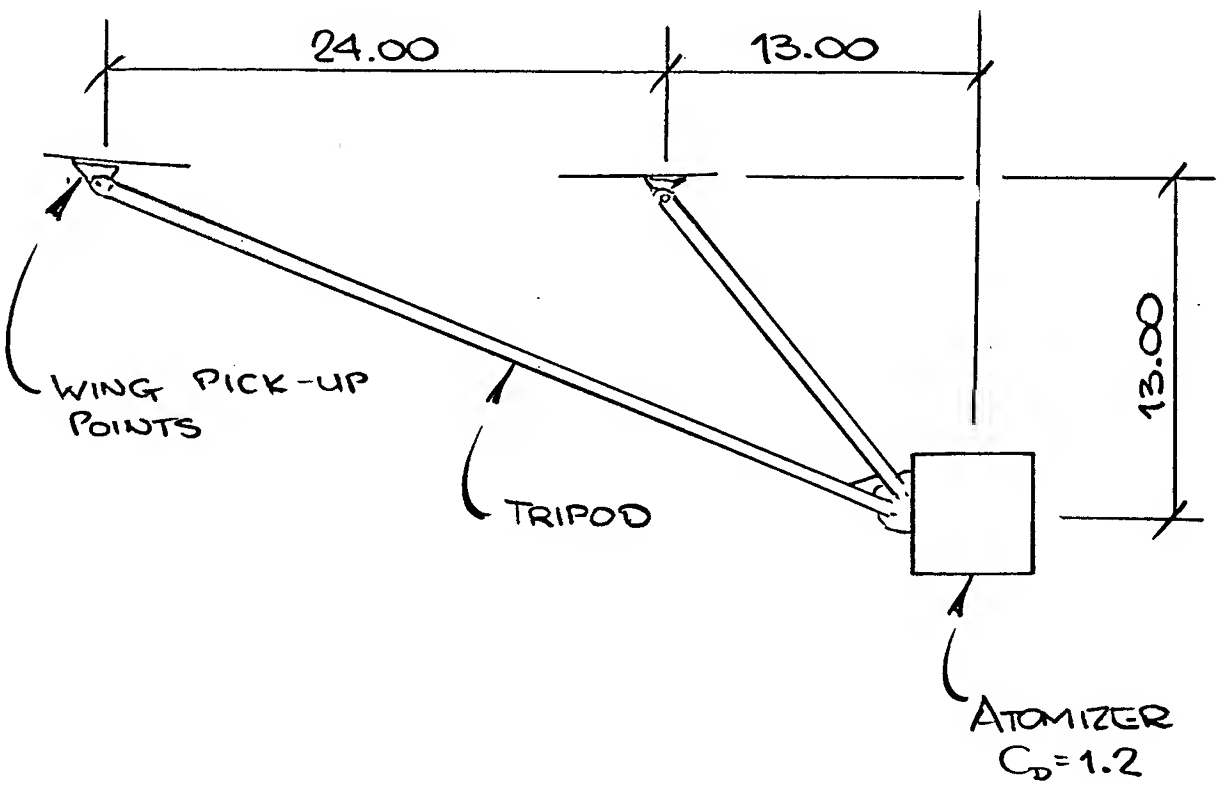
*ADDITIONAL ON MODEL 182 (1962 & on)
44.0 MODELS 180 & 185; MODEL 182 (Prior to 1962)
45.0 MODEL 182 (1962 & on)


24.00
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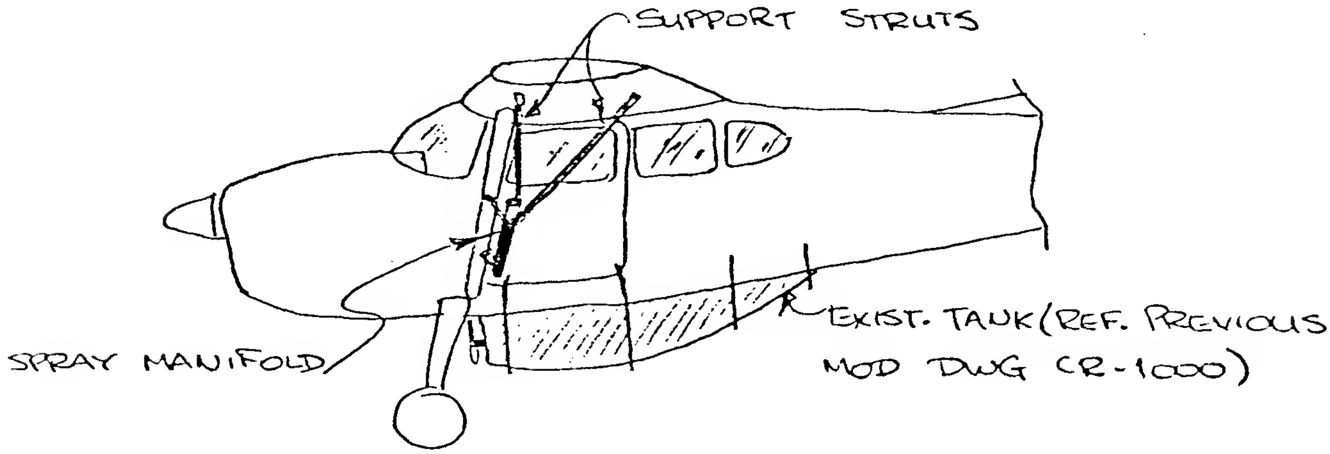
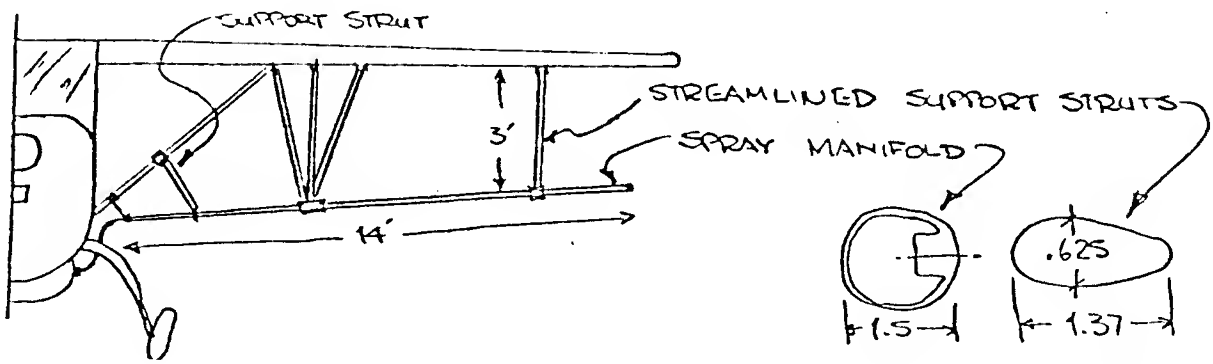
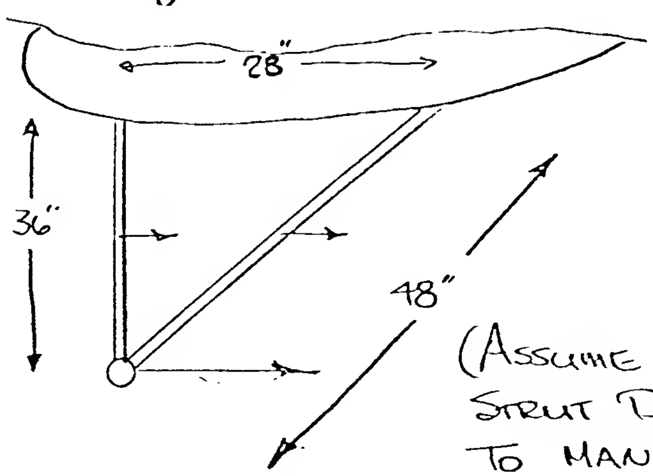
WING PICK-UP POINTS
TRIPOD
ATOMIZER
C_D=1.2

Exhibit II a.

TWO SPRAY MANIFOLD ASSEMBLIES ARE MOUNTED, ONE UNDER EACH WING, BY MEANS OF A SERIES OF STRUTS CLAMPED TO THE MANIFOLD & ATTACHED TO THE WING PICK-UP POINTS (REF. PREVIOUS MOD. "ILUST.N OF CROP SPRAYING SYST." M.O.T. APPROVAL No. 0-72-225).







(ASSUME HALF OF VERTICAL STRUT DRAG TRANSMITTED TO MANIFOLD)

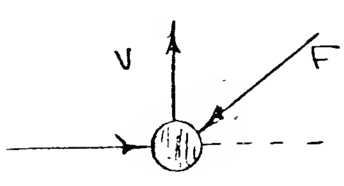


Exhibit II b.

CROP SPRAYING BOOM FOR CESSNA 185 (B)

CESSNA 180 and 185 SKYWAGON (USA) **First flights 1953/1960**

Light transport

Data: Model 185
Power plant: One Continental IO-520-D piston engine (300 hp)
Wing span: 35 ft 10 in (10·92 m)
Length overall: Landplane, skiplane 25 ft 9 in (7·85 m) Floatplane 27 ft 0 in (8·23 m) Amphibian 27 ft 6 in (8·38 m)

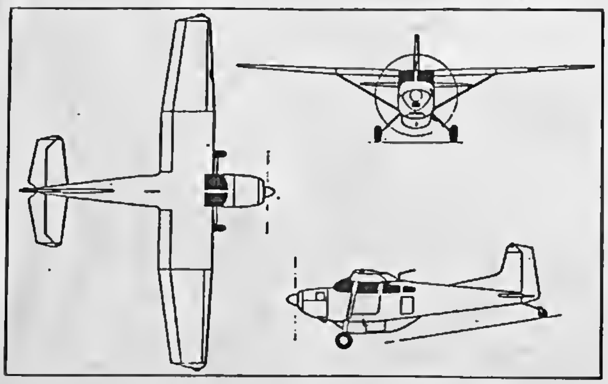


Photo and Drawing: Model 185

Max T-O weight: Landplane, skiplane 3 350 lb (1 519 kg) Floatplane 3 320 lb (1 506 kg) Amphibian, land take-off 3 265 lb (1 481 kg) Amphibian water take-off 3 100 lb (1 406 kg)
Max cruising speed (75% power) at 7 500 ft (2 285 m): Landplane 147 knots (169 mph; 272 km/h) Floatplane 135 knots (155 mph; 249 km/h) Amphibian 129 knots (149 mph; 240 km/h) Skiplane 130 knots (150 mph; 241 km/h)
Max rate of climb at S/L: Landplane 1 010 ft (308 m)/min Floatplane 960 ft (293 m)/min Amphibian 970 ft (296 m)/min
Service ceiling: Landplane 17 150 ft (5 229 m) Floatplane 16 400 ft (5 000 m) Amphibian 15 300 ft (4 663 m)
Range at econ cruising speed at 10 000 ft (3 050 m), long-range tanks, no reserve: Landplane 933 nm (1 075 miles; 1 730 km) Floatplane 842 nm (970 miles; 1 561 km) Amphibian 790 nm (910 miles; 1 464 km) Skiplane 807 nm (930 miles; 1 497 km)
Accommodation: Up to six persons can be carried (including pilot); or the aircraft can be arranged to carry fewer passengers and 400 lb (181 kg) of baggage; or all passenger seats can be removed for freight carrying
Number ordered/built:
5 287 Model 180 Skywagon by January 1973
2 015 Model 185 Skywagon by January 1973, incl more than 300 for MAP distribution by USAF to more than a dozen air forces

EXHIBIT III

ECL 232 B

H. AASS AERO ENGINEERING LTD

Engineering Report No. 943

Date 30, MAY 1975

Page 1 of 7

TITLE: INSTALLATION OF SPRAY BOOM

AIRCRAFT MFG.: CESSNA

MODEL: 185 E

REG. NO.: CF - BZA

EXHIBIT IV

P.O. BOX 182, R.R. NO. 5, HUNT CLUB ROAD, OTTAWA, ONTARIO K1G 3N3 – TEL. (613) 521-0180

Aircraft Owner CHEMICAL CONTROL RESEARCH INSTITUTE

Work Requested by C.C.R.I

Report prepared by P. A. MOYLAN
H. AASS AERO ENGINEERING LTD.

Checked by H. Aass

SCOPE:

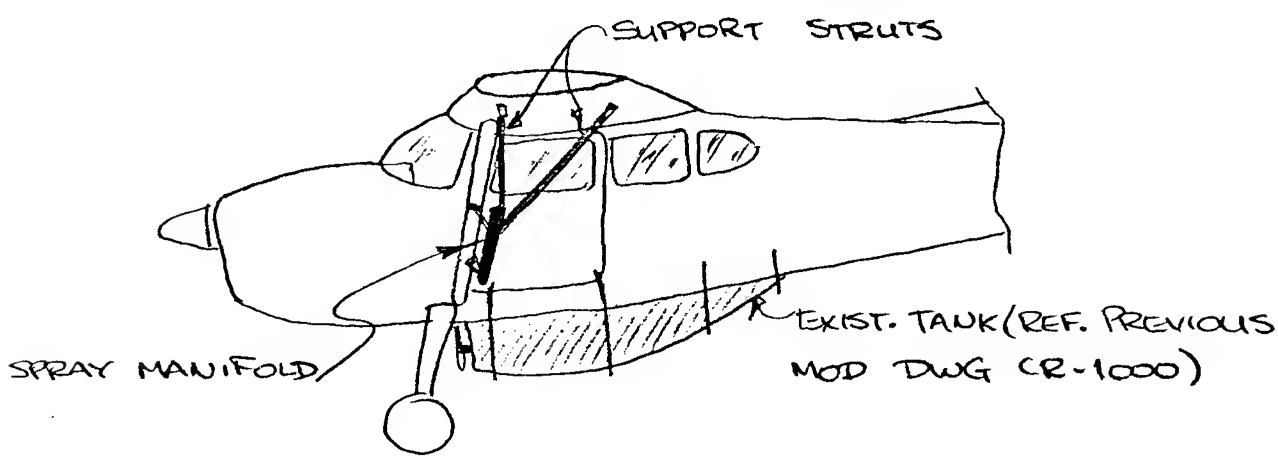
THIS REPORT COVERS THE ENGINEERING REQUIRED FOR THE APPROVAL OF THE INSTALLATION OF SPRAY BOOM ON A CESSNA ACFT., MODEL 185 E, IN STOL CONFIGURATION.

REFERENCES:

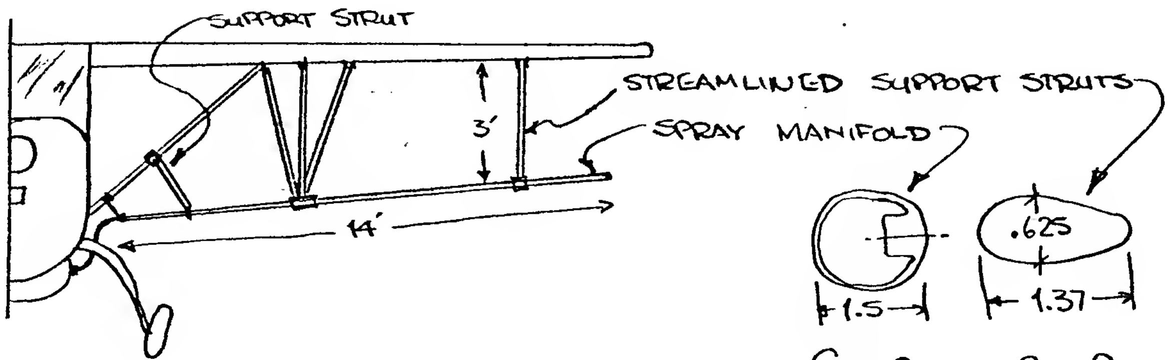
1. CERTIFICATION BASIS:
   PART 3, CAR EFFECTIVE MAY 15, 1956 AS AMENDED BY 3-1 THRU 3-5
2. H.A.A.E ENGRG REPORT NO. 479
3. ARB AIRWORTHINESS APPROVAL NOTE 7681
4. CHEMICAL CONTROL RESEARCH INSTITUTE DWG. NO. CR-1004. REV. A
5. REQUIREMENTS COMPLIANCE PROGRAM DATED 10, APR 1975 PREPARED BY HAAE.

DESCRIPTION:

TWO SPRAY MANIFOLD ASSEMBLIES ARE MOUNTED, ONE UNDER EACH WING, BY MEANS OF A SERIES OF STRUTS CLAMPED TO THE MANIFOLD & ATTACHED TO THE WING PICK-UP POINTS (REF. PREVIOUS MOD. "INSTN OF CROP SPRAYING SYST." M.O.T. APPROVAL NO. 0-72-225).



ANALYSIS:



$C_D = .6$ $C_D = .2$

FRONTAL AREA:

- MANIFOLD $\dfrac{14 \times 1.5}{12} = 1.75 \text{ ft}^2$
- STRUTS $\dfrac{4\frac{1}{2} \times 3 \times .62}{12} = .57 \text{ ft}^2$

LOAD DUE TO DRAG:

- MANIFOLD: $F_M = C_D \cdot \frac{\rho}{2} V^2 A$ (ASSUME V_{MAX} TO BE 250 ft/s)

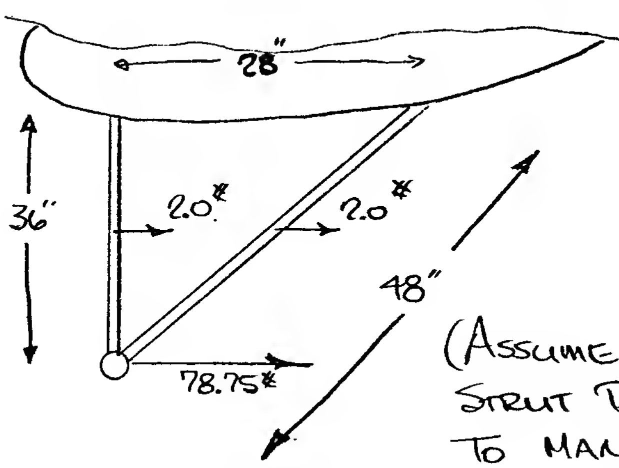
$F_M = .6 \times 1.2 \times 10^{-3} \times 250^2 \times 1.75$

$= 78.75$ lbs.

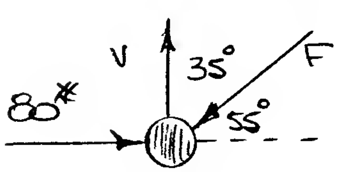
- STRUTS: $F_S = .2 \times 1.2 \times 10^{-3} \times 250^2 \times .57$

$= 8.4$ lbs

or Approx 2.0 lbs. / strut



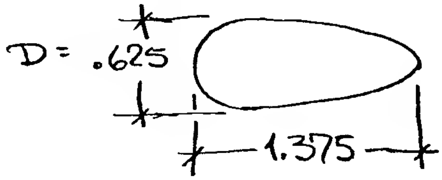
(ASSUME HALF OF VERTICAL STRUT DRAG TRANSMITTED TO MANIFOLD)



$F \cos 55° = 80^{\#} \rightarrow F = 140^{\#}$

$F \sin 55° = V = 115^{\#}$

LOOKING AT AFT. STRUTS: (in compression)



EQUIV. ROUND TUBE:

$D = .5714d$ (REF. Bruhn C4.15)

$.625 = .5714d$

$d = 1.09 \doteq 1.125$

$\therefore A = .2165 \quad \rho = .2185$

For $L' = L/\sqrt{c}$ ($c = 1 \rightarrow$ pin jointed)

$L' = 48''/\sqrt{1}$

$L' = 48''$

$$L'/\rho = \frac{48}{.2182} = 220$$

$$F_c = \frac{\pi^2 E}{(L'/\rho)^2} \quad (\text{WHERE } E = 10.3 \times 10^6)$$

$$= \frac{9.86 \times 10.3 \times 10^6}{(220)^2}$$

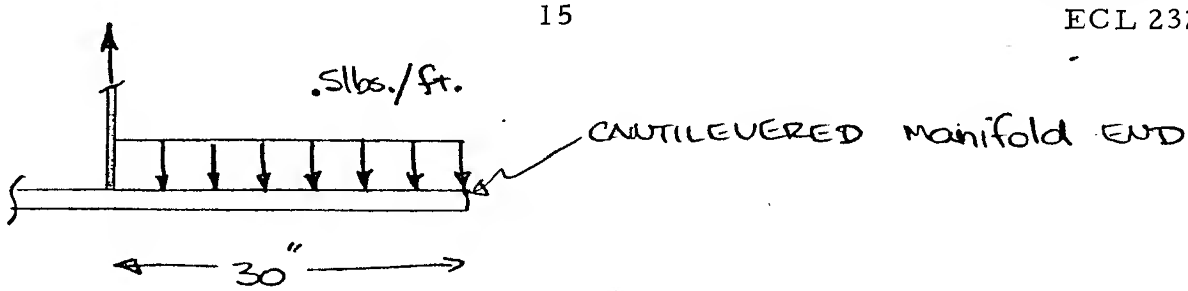
$= 2100$ psi – allowable stress

$$\text{MAX. STRESS} = \frac{F}{A} = \frac{140^*}{.2165\ in^2} = 646.6 \text{ psi.}$$

THEREFORE IN EACH STRUT:

$$\frac{646.6 \text{ psi}}{2} = 323.3 \text{ psi}$$

$$R.F. = \frac{2100 \text{ psi}}{323.3 \text{ psi}}$$ – – – – – – – – – – – – – O.K.



MAX. BENDING MOM. $= \dfrac{wL}{2}$

$= (.5 \times 2.5 \times 8) \times \dfrac{30}{2}$ (8g max)

$= 150$ in lbs.

MAX. ALLOWABLE σ $= \dfrac{EI}{y}$

$I = \frac{\pi}{4}(r_o^4 - r_i^4)$
$= .785(.0937)$
$= .0735 \text{ in}^4$

$= \dfrac{30{,}000 \times .0735 \text{ in}^4}{.75}$

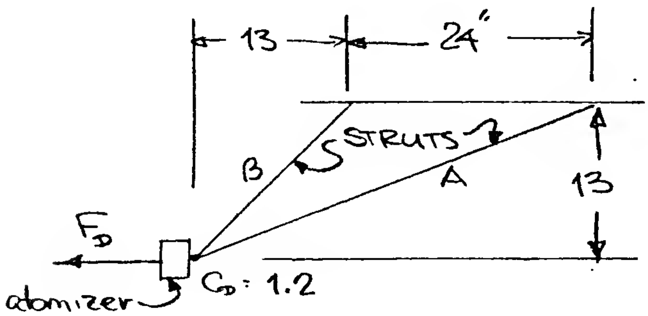
$= 2950$ in lbs.

R.F: $\dfrac{2950 \text{ in.lbs.}}{150 \text{ in.lbs.}}$ - - - - - - - - - - OK.

these figures are conservative since the inboard support brkt. & support strut are ignored.

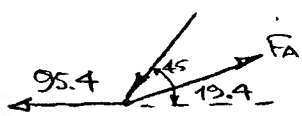
Vertical struts ARE IN tension & ARE considered, by inspection, Adequate.

To determine whether wing attachment points are adequate, we will look at loading conditions of these points in previous installation. (Ref. C.C.R.I dwg. no. CR-1000 & HAAE REPORT No. 479)



$F_D = C_D \cdot \frac{\rho}{2} V^2 A$ (where $V = 250$ ft/sec. & $A = \pi r^2 = \frac{3.14 \times 7''}{144} = 1.06$ ft^2

$F_D = 1.2 \times 1.2 \times 10^{-3} \times 250^2 \times 1.06$
$= 95.4$ lbs.



$\Sigma F_y = 0$
$F_A \sin 19.4° = F_B \sin 45°$
$F_A = 2.13 F_B$

$\Sigma F_x = 0$
$\cdot -95.4 + F_A \cos 19.4° - F_B \cos 45° = 0$
$= -95.4 + 2.13 F_B \cos 19.4° - F_B \cos 45° = 0$
$1.30 F_B = 95.4$
$\therefore F_A = 156.06$ lbs.

Due to landing loads, attachment points must withstand both tensile & compressive loads. Since in the previous installation, these points were subjected to loads (156 lbs MAX.) greater than those encountered in the present modification, they are considered structurally adequate.

RPMaylan

CROP SPRAYING BOOM FOR CESSNA 185 (C)

With the analysis completed, it appeared that the new spray system provided a 20% margin of safety over the old.

Using the original Sorenson drawings, considering the 5° angle of inclination Lorne had mentioned, and references to the many Cessna 185's parked in the field in front of the hangar, I designed a series of four new struts. Three struts would be attached to the first set of pick-up points and one to the forward bracket of the second set. (Exhibit V). The end fittings were produced by inserting a steel tongue into either end of the steel tube, flattening the walls and welding the tongue in place. My intent was to produce struts that were not only rigid, but would not yield due to bending caused by air loads. The wing bracket attachment holes in the struts were pre-drilled but the holes in the lower ends were left undrilled. They would be drilled on installation, and this would give as much leeway as possible during fitting. For holding the spray boom small steel brackets were made from my sketches and fitted to the six inch sample of boom I had. These would be attached on installation, to the struts with #10 bolts and nuts, and to the boom with jubillee clamps, (a commercial hardware item which can be attached quickly). (Exhibit VI a.) These brackets could be moved along the boom to suit the tripod arrangement allowing for another degree of freedom. A larger steel bracket was fabricated to attach the boom end to the wing support strut (Exhibit VI c.) Since this wing strut is identical for all models of this aircraft, it was simple to ensure that it would fit properly. A flexible rubber-nylon hose would feed the booms from existing outlets on either side of the main holding tank. This again added a certain degree of freedom for the installation.

When the aircraft returned in two weeks, the kit which had been manufactured in the shop, was ready for installation. The aircraft was immediately wheeled into the hangar and two mechanics began dismantling the old system. In a scant five hours, the modified craft was ready to take to the air.

"Quite a hairy looking rig," Haakon murmured to me as he glanced over the doubtful bird in front of him.

"I hadn't realized the booms were so damn long" he continued. "I think we better let Paul have a look."

Paul Hartman was the company DAR test pilot. Within an hour, he was poking at our modification as if it were a prickly cactus.

"Think it'll fly?" he asked glancing in my direction with that knowing smile of his.

"It better." I retorted.

Paul climbed aboard and within minutes had completed his "run-up" (aircraft engine and systems check out) and was taxiing down the runway.

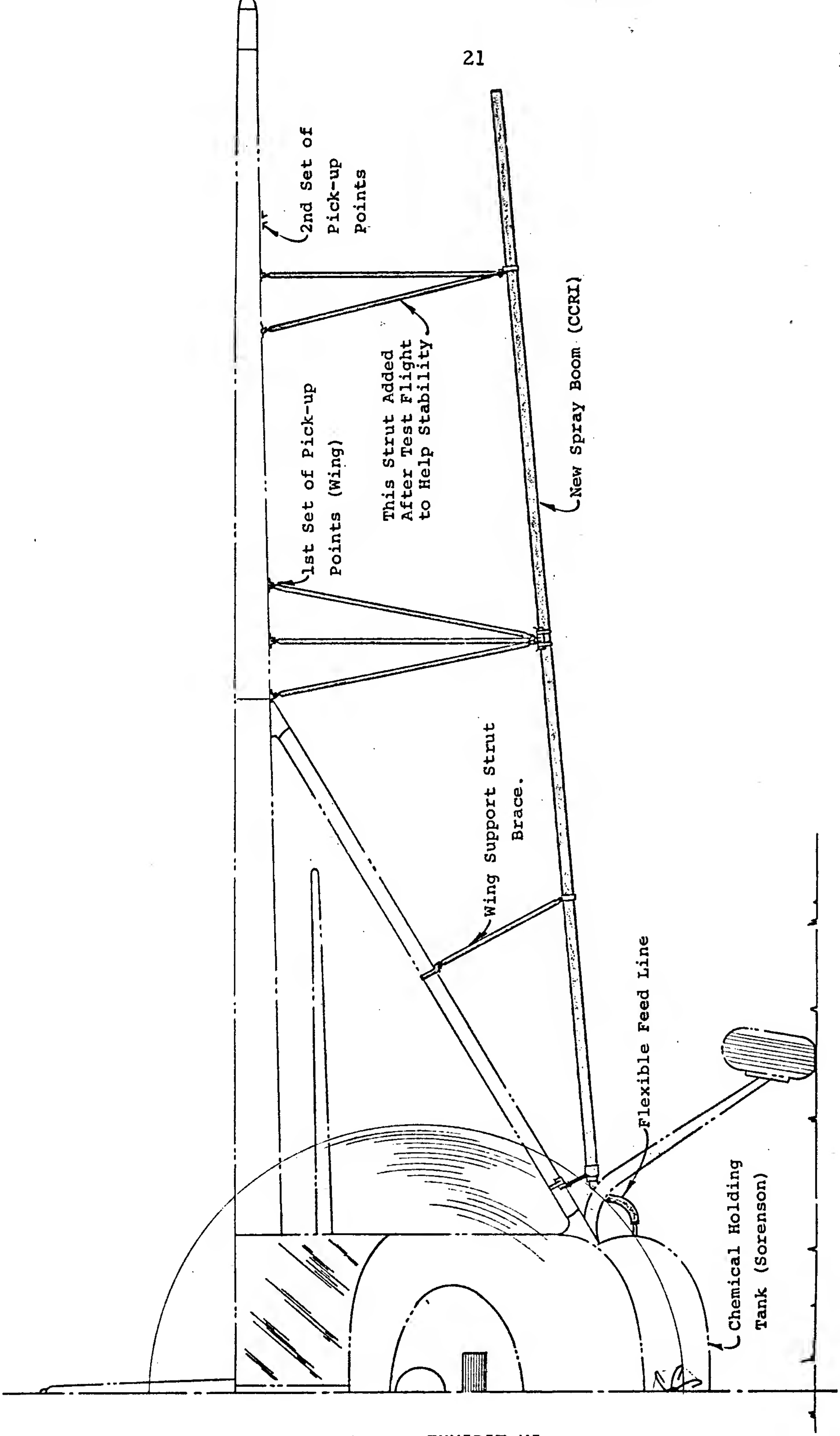
Three quarters of an hour later, Paul was back in our office explaining that during the flight, he had noticed some severe vibration at the outer ends of each boom in the horizontal or "line of flight" mode. After a short discussion, we concluded that this was due to the single outer strut acting like a hinge at either end. Haakon suggested that a second strut, utilizing one of the rear brackets of the outboard set of pick up points, be added to stabilize the outer section of boom. Although this presented a small delay, it was not a catastrophic development. Within two hours the aircraft was ready for a second test flight. A circuit around the airport was enough to tell Paul that everything was

airworthy. He landed the aeroplane and handed over the keys to Lorne Pollock with a reassuring smile.

Lorne climbed into the cockpit, grinned, and started his engine. He had two or three hours on his deadline and he wouldn't have to "blow rooves off" to make it in time.

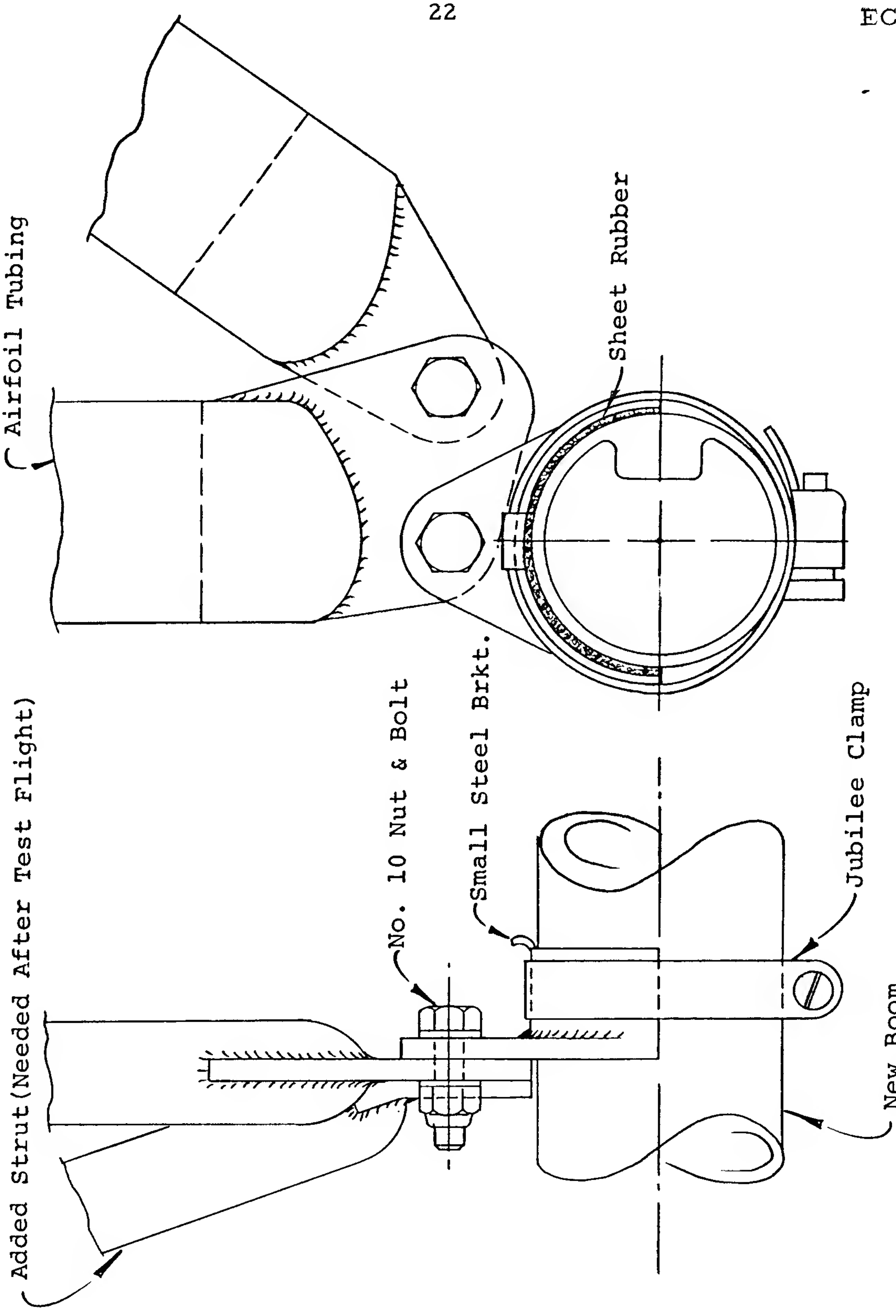
* * * * * *

EXHIBIT V



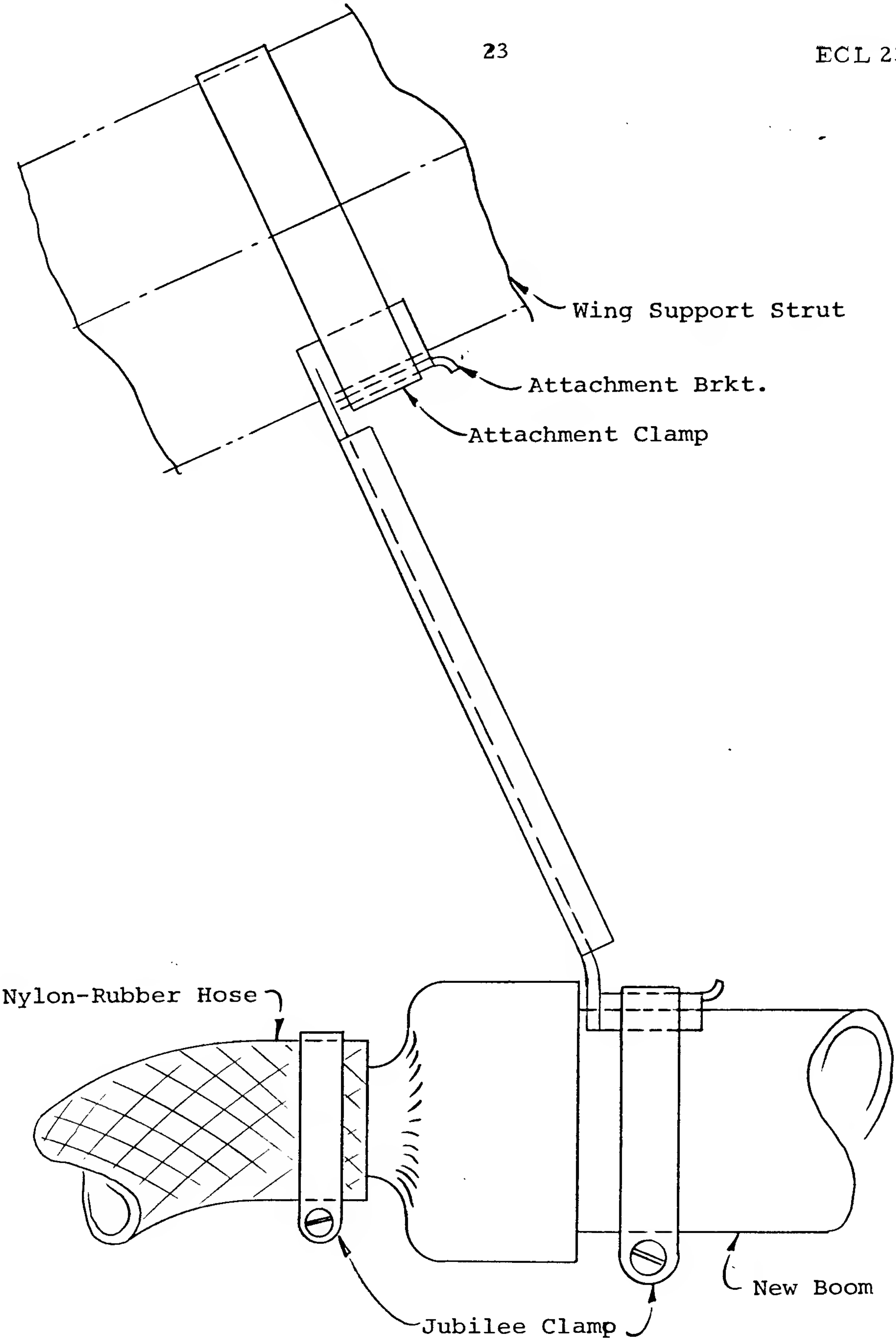
Front View of Cessna 185 With New Spray Boom Installed

EXHIBIT VI a



Outboard Boom Attachment

Exhibit VI b.



Attachment to Wing Support Strut

Exhibit VI c.